ECOLOGY AND BIOLOGICAL PRODUCTION OF LAKE NAKA-UMI AND ADJACENT REGIONS -5. SEASONAL CHANGES IN DISTRIBUTION AND ABUNDANCE OF SOME DECAPOD CRUSTACEANS-

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ECOLOGY AND BIOLOGICAL PRODUCTION OF LAKE NAKA-UMI AND ADJACENT REGIONS

5. SEASONAL CHANGES IN DISTRIBUTION AND ABUNDANCE OF SOME DECAPOD CRUSTACEANS

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With 28 Text-figures and 2 Tables

Introduction

During the ecological survey of Lake Naka-umi and adjacent regions, carried out in the period 1958–1962 to meet the request of the Shimane Prefectural Government as described elsewhere (MIYADI and others, 1964), a large number of biological samples were collected from various habitats over most of the area. These samples contained a variety of decapod crustaceans.

Knowledge of the crustaceans of the Japan Sea coast of Japan has been accumulated rather poorly and even the faunal study is surprisingly scarce. In fact, it appears to be quite strange that, while the coastal faunas on the Pacific side have been studied extensively and the ecology has been elucidated well for some of shallow water crustaceans there, little attention and contribution have been extended to those on the Japan Sea side.

An extensive description of the crustacean bottom fauna of the Japanese waters was first made in the classical work of YOKOYA (1933), based on the Sôyô-maru collection. The intensive studies followed along the Japan Sea coast were mostly directed to the commercial crustaceans, such as *Pandalus hipsinotus* and *Chionoecetes opilio*, trawled also on the continental shelves. Recently, OUCHI (1960) described the bottom fauna off the coast of Niigata and Yamagata Prefecture, depths ranging from 30 metres to 150 metres, and recorded 23 species of brachyurans and 17 species of macrurans. Decapod crustaceans of inshore areas of much shallower waters, particularly off the western part of the coast, are however still left rather unaccounted.

A series of works by MIYADI and others (1942, 1945, 1952, 1954), three of which are concerned with the area of the present study, contain composition records of the bottom faunas and ecological analysis on types of distribution of bottom animals in bays and brackish lakes. The materials on which these discussions are based are those sampled by the square bottom grab of Ekman-

Birge type, and larger crustaceans are scarcely treated in them. The works on the bottom communities by YAMAMOTO and MATSUMOTO (1955) for Lake Hachirô-gata and by KIKUCHI (1964) for Lake Shinji-ko and Lake Naka-umi are also based on the materials collected with bottom grabs and little references are made to larger crustaceans.

Apart from these works, a specific account of ecology is given for a commercial shrimp, *Metapenaeus monoceros*, in Lake Naka-umi by OTA (1949). In the work of HARADA (1963) a brief presentation appears of the composition of amphipod crustaceans inhabiting among *Sargassum* growth in Lake Naka-umi.

In such situation of our knowledge, and particularly when the area is to undergo drastic alteration from salt water to fresh water, it is thought to be of value to present records of occurrence of larger decapod crustaceans in Lake Naka-umi and adjacent regions in their original conditions. Since the primary object of the survey was to obtain materials and informations for the estimation of possible effects of environmental alterations on fisheries and of biological production, the survey had been concentrated more or less to the fishery resources and dominant species. These animals were collected mostly with gears of commercial fisheries, including some with modifications suitable for handling, and from commercial catches, whereas smaller and rare species were somewhat neglected. Eventually, the collections are by far complete for the detailed faunal study, and, on the other hand, for some members which have been caught and have been observed sufficiently enough, population compositions and seasonal fluctuations in abundance and distribution are only justifiably treated.

I am grateful to Prof. D. MIYADI for much suggestions and to Dr. H. KAWANABE for a great deal of work in planning the survey. All materials and records were gained through collaboration of the members of the group, particularly Dr. S. FUSE, Mr. S. TAKAMATSU, Mr. T. SUNAGA, Mr. I. MAKI, Mr. M. AZUMA and Mrs. Yoko Tezuka SAITO, to whom my thanks are due. I am also indebted to the personnels of the Prefectural Government and fishermen of the district who assisted in field collection. Prof. S. MORI and Dr. T. TOKIOKA have given me suggestions and criticisms during the preparation of the manuscript, to whom I am particularly indebted.

Environmental Features of the Regions

The general features of the regions were summarized by MIYADI and others (1964). The climate of the district is very severe in winter, directly exposed to the prevailing north-west wind from the Continent, while the seas are strongly influenced by the warm Tsushima Current, the main flow of which is travelling offshore up northwards.

Miho Bay is fully exposed to the east and its floor slopes gently to the open sea up to 30 metres in depth. The well-developed shore of clean sand extends from the south to the north-west corner of the Bay, resulted by strong wave-action and clockwise current. The bottom is mainly muddy with few scattered rocky outcrops at the middle. *Zostera* belts cover the shallow bottom in places along the sandy shore. The coast of Jizo-zaki Point sheltering Miho Bay from the north are extensively rocky and steep, and are supporting thick *Sargassum* growth from winter to spring.

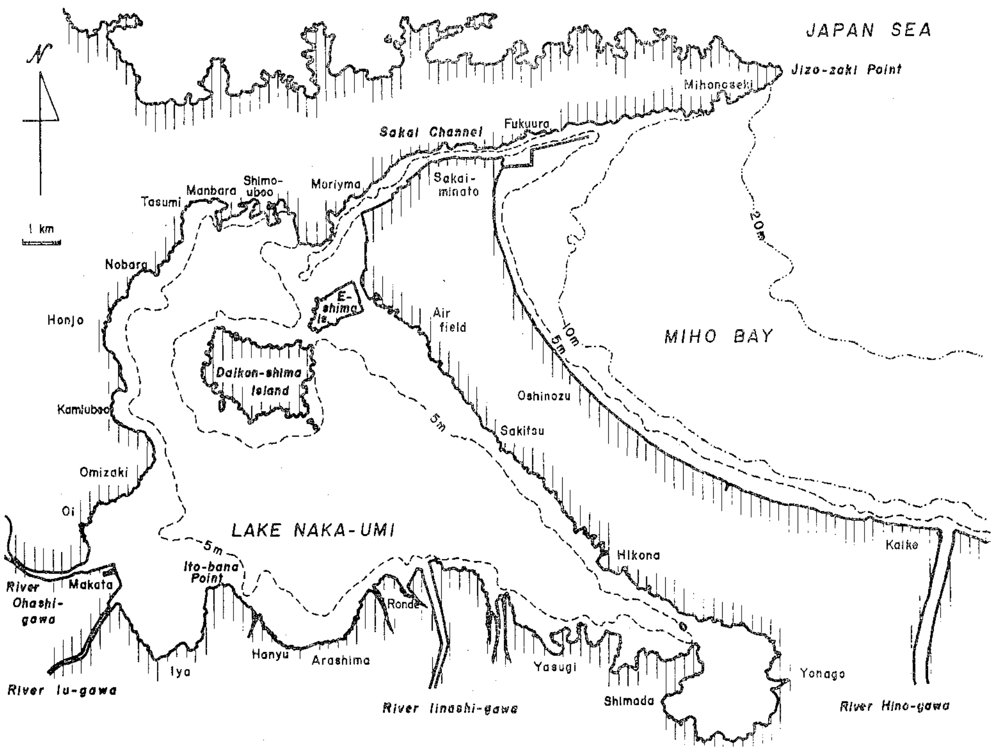

Fig. 1. Chart of Lake Naka-umi and Miho Bay showing depths and fringing places.

Separated by the sand bar from Miho Bay, Lake Naka-umi is generally shallow, less than 10 metres in depth, and the bottom is predominantly consisted of thick, fine mud. The rocky shoreline bounds the northern part, which is indented at intervals by muddy beaches. The islets are also surrounded by rocky coasts and boulders. *Sargassum* growth develops on these shallow rocky bottoms, the amount of which decreases to the west. The main basin of the Lake is surrounded by muddy shores and stone banks. The aquatic vegetations are growing over much of the fringing muddy bottoms, particularly that of *Zostera marina* overwhelming off Manbara to Honjo, around the mouth of River

Ohashi-gawa, near the mouth of River Iinashi-gawa and along the east coast.

Sakai Channel forms the sole outlet to the sea for the waters flowing through Lake Naka-umi from Lake Shinji-ko and marginal rivers and streams. Tidal currents are fairly strong, sometimes reaching to about 1 knots. The south side of the Channel is lined by concrete wharves for fishery fleets, while on the north the coast is rather unaltered and is consisted of rocks and muddy or sandy beaches. *Sargassum* belts on rocks and *Zostera* belts on muddy beds are found along the north coast.

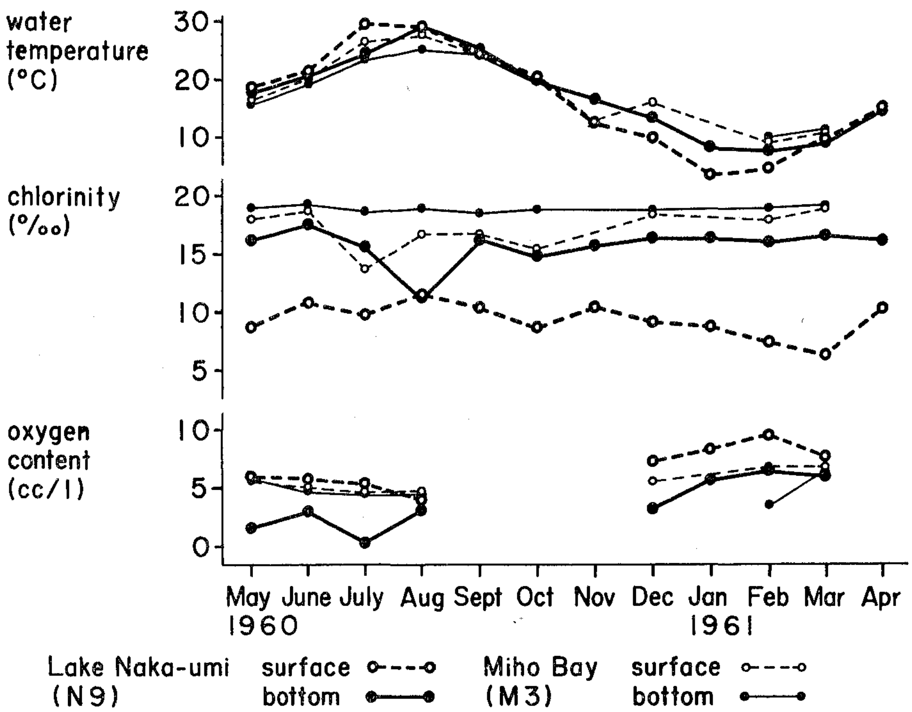

Fig. 2. Seasonal fluctuations in hydrographic conditions of Lake Naka-umi and Miho Bay at the surface and the bottom.

The hydrographic conditions vary greatly from Miho Bay to Lake Naka-umi and show a marked gradient. The fluctuations of these conditions generally greater in Lake Naka-umi. Temperature fluctuation is most extreme at surface in Lake Naka-umi, ranging from 3.9°C to 29.6°C, but bottom water is about 4°C warmer in winter. The range of temperature fluctuation is from 10.5°C to 25.3°C at bottom layer in Miho Bay.

Tidal differences in Miho Bay are relatively small, usually 0.3 metres, while fairly a large amount of fresh water is flowing through, and surface chlorinities remain generally low, between 6‰ and 11‰, over most of Lake Naka-umi.

The high chlorinity water entering into the Lake from Miho Bay is not diluted by the surface water and the chlorinity of the bottom water of Lake Naka-umi is only slightly lower, 2‰ to 3‰, than that of Miho Bay.

Owing to these properties of water vertical mixing does not occur in summer and oxygen contents of bottom water occasionally decrease below 1 cc/L in Lake Naka-umi.

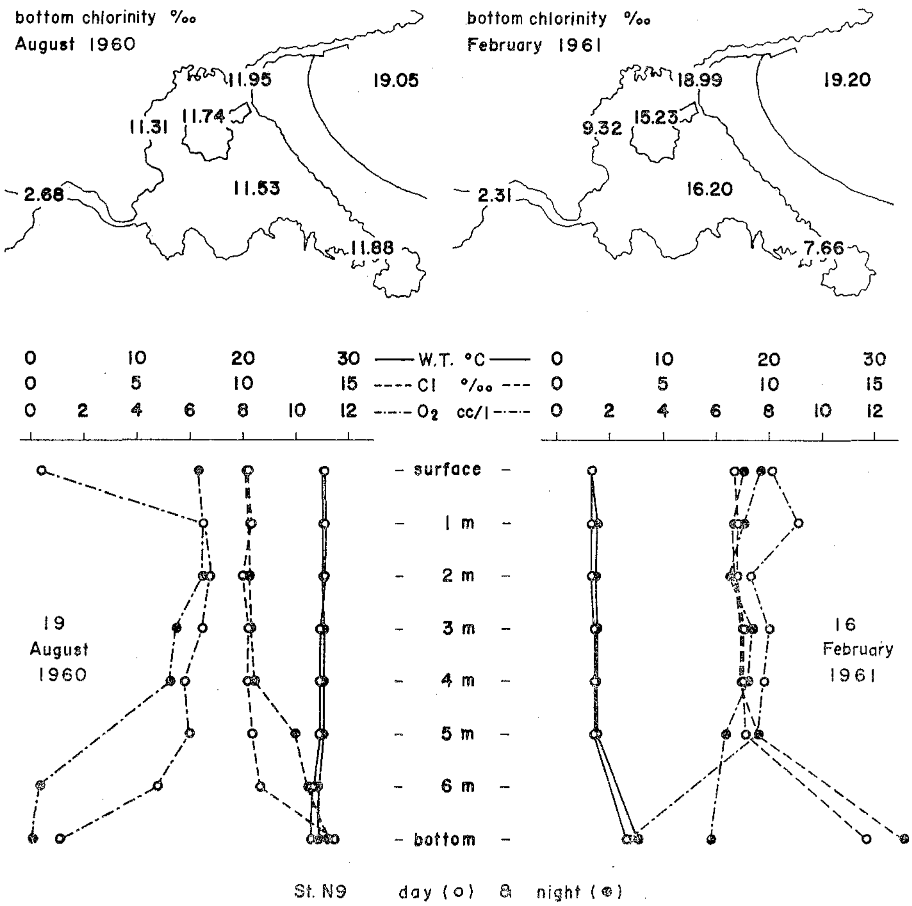

Fig. 3. Comparison of bottom chlorinities over the regions in summer and winter (above), and day and night change of hydrographic conditions at various depths at the middle of Lake Naka-umi.

Phosphorus salts received by Lake Naka-umi and retained there are assessed to be larger (MORI, 1964). The water in Lake Naka-umi is noticeably much more turbid than is in Miho Bay, whereas in Sakai Channel pollutions by sewages and dumpings from ships have been frequently experienced to reach the extremes.

Materials and Methods

Series of monthly samples were obtained from the varying sites according to the characteristics of the commercial fishing gears used, thus enabling to provide ecological informations of various animals as well as to sample more species inhabiting the area. In conjunction with monthly samples, day and night collections were made in order to add knowledge regarding the daily activities of animals. Even though these samples failed in accurate quantitative estimation of populations, they might, at least, be permissible to compare if they were obtained under relatively identical conditions of weather, sea bed and operation.

Animals caught were washed and preserved in 10% formalin on board, and were subsequently sorted out into systematic groups. The sex was recorded and measurements were taken to carapace length, body length and weight for each of all specimens, only when the number of individuals of a species in a sample was small, that was the case for most larger species. As in many samples the specimens are often damaged in the abdomens, the carapace length from the posterior rim of the eye socket to the posterior mid-dorsal border of the carapace, measured to 0.1 mm by transfering it on to a scale by calipers, is taken to be of advantage in analysis of the results.

The characteristics in structure and in operation of the gears used are only mentioned here briefly to include considerations of their limitations and advantages.

Kogai-ami (*a trawl*). A large baglike net is attached to two bamboo timbers sticking out from a boat on its bow and stern ends and thus keeping the mouth of the net open. The net is lowered away over one side of the boat, and the rope leading to an anchor on the opposite side is heaved in by hands to drag the net over the bottom accordingly. The net was approximately 5 metres wide at its mouth and the distance travelled at each operation was about 40 metres. Collections were made monthly at sampling sites selected in the fringing parts of Lake Naka-umi.

Masu-ami (*a guiding barrier*). This is a set net, a large structure supported on poles, consisted of a guiding range extending from the shore over a considerable distance and a near-square pound at its offshore end. About a dozen of commercial fishing barriers were selected over the regions to obtain the regular samples of catches. Catchability depended entirely on the migratory activity of animals. Consequently, the samples appeared hardly to approximate the true composition of the fauna at each site, but had much to suggest on the ecology of animals caught. Daily records of commercial catches were also gathered from fishermen.

Kobukuro-ami (*a filter net*). This gear is also a set net and is worked only along the narrowed strait where the tidal streams are sufficiently strong. The net of ordinary baglike shape, 3 metres by 2 metres at the mouth approximately, was supported on poles and was set anew at each time of tidal flux to receive the current just below the sea surface. The samples of catches were obtained by monthly operation in Sakai Channel and River Ohashi-gawa. Catchability of the net was incorporated by tidal drifts and activities of animals and, incidentally, its catches were inadequate to represent the fauna of the site and to lead to the estimation of the populations.

Tate-ami (*a trammel*). The net is made up of three sheets of nylon lint, the middle one with smaller meshes and two armourings with larger meshes. Fishing by trammels was restricted mostly in rocky areas of Lake Naka-umi and Miho Bay. Catchability also depended largely on active movements of animals and was selectively different for animal species. This gear was quite effective for larger crabs, but the samples provided little of the evaluation of the entire crustacean fauna.

The lints of these gears were rather large-meshed; about 6 mm across for the trawl and the filter net, about 3 cm across for the guiding barrier and about 4.5 cm across for the inner lint of the trammel. Thus the limitations were imposed to the minimum sizes of animals captured by them.

Occurrence of Decapods

The species of decapod crustaceans caught during the survey are listed in Table 1 with the designations of the regions of their occurrence. More than 61 species have been distinguished altogether from the samples, of which 55 species have been identified. Among them, brachyurans number 18, anomurans 4, macrurous reptantians 2, carideans 15, and 16 species belong to the penaeidea.

Although the present results are based on the materials collected during the survey, they should be regarded carefully in interpretation as the positive indications of the occurrence of the species, but not as the evidence of the consistency of them to inhabit the regions, nor as that of their absence from any particular region. Since the sampling methods have been different from area to area, it should not be expected that the animals have been collected with identical intensities over the whole area. For example, there are noticed many species that have been collected only in Sakai Channel. However, it seems unlikely in most of these species that they can sustain their populations restricted to there. This and the fact that the largest number of the species has been recorded for Sakai Channel are perhaps partly due to that the collecting gears used in Sakai Channel have been most various.

The species inhabiting the salt-water regions overnumber the freshwater inhabitants. 30 species of decapods have been collected in the coastal areas of

Table 1. A list of species and their occurrence in the regions associated with Lake Naka-umi. Abbreviations for the regions are S as Lake Shinji-ko, N as Lake Naka-umi, C as Sakai Channel and M as Miho Bay. *f* means that the species is fished by commercial fishermen.

Taxon	Occurrence
Grapsidae (Brachyura)	
Eriocheir japonicus DE HAAN	S-N-C-M
Hemigrapsus penicillatus (DE HAAN)	N
Pinnotheridae (Brachyura)	
Pinnixa rathbuni SAKAI	M
Pinnotheres sp.	N
Goneplacidae (Brachyura)	
Eucrate crenata DE HAAN	C-M
Portunidae (Brachyura)	
Charybdis (Charybdis) acuta (A. MILNE-EDWARDS)	M
C. (C.) japonica (A. MILNE-EDWARDS)	N-C-M *f*
C. (Gonioneptunus) bimaculata (MIERS)	N
Portunus gladiator (FABRICIUS)	C-M
P. hastatoides (FABRICIUS)	M
P. pelagicus (LINNAEUS)	S-N-C-M *f*
Ovalipes punctatus RATHBUN	M
Parthenopidae (Brachyura)	
Lambrus (Platylambrus) validus DE HAAN	M
Zalasius dromiaeformis (DE HAAN)	M
Maiidae (Brachyura)	
Achaeus sp.	N
Pugettia spp.	C
Leucosiidae (Brachyura)	
Leucosia longifrons DE HAAN	M
Philyra pisum DE HAAN	N
Raninidae (Brachyura)	
Ranina ranina (LINNAEUS)	C
Calappidae (Brachyura)	
Matuta lunaris (FORSKÅL)	C
Dorippidae (Brachyura)	
Drippe dorsipes (LINNAEUS)	C
Paguridae (Anomura)	
Pagurus trigonocheirus (STIMPSON)	M
Paguristes digitalis STIMPSON	C
Callianassidae (Anomura)	
Callianassa petalura STIMPSON	C
Upogebia major (DE HAAN)	C
Potamobiidae (Astacura)	
Procambarus clarki (GIRARD)	N
Scyllaridae (Palinura)	
Scyllarus kitanoviriosus HARADA	M
Crangonidae (Caridea)	
Crangon affinis (DE HAAN)	N-C-M *f*
Sclerocrangon angusticauda (DE HAAN)	C
Processidae (Caridea)	
Processa japonica (DE HAAN)	M
Palaemonidae (Caridea)	
Macrobrachium australe (GUÉRIN MÉNÉVILLE)	S
M. nipponense (DE HAAN)	S-N *f*
Palaeman (Exopalaemon) orientis HOLTHUIS	S-N
Palaemon (Palaemon) ortmanni RATHBUN	N
P. (P.) pacificus (STIMPSON)	N-C-M
P. (P.) paucidens DE HAAN	S-N
P. (P.) serrifer (STIMPSON)	S-N-C
P. (P.) sp.	N
Hippolytidae (Caridea)	
Heptacarpus geniculatus (STIMPSON)	C
H. sp. (aff. *H. minutus* YOKOYA)	C
Latreutes planirostris (DE HAAN)	C
Alpheidae (Caridea)	
Alpheus brevicristatus DE HAAN	N-C-M *f*
A. japonicus (MIERS)	M
A. rapax DE HAAN	M
Athanas spp.	? M
Penaeidae (Penaeidea)	
Metapenaeus affinis (H. MILNE-EDWARDS)	C
M. monoceros (FABRICIUS)	S-N-C-M *f*
Metapenaeopsis acclivis (RATHBUN)	M
M. barbatus (DE HAAN)	C
M. durus KUBO	C-M
M. dalei (RATHBUN)	M
M. lamellatus (DE HAAN)	C
M. mogiensis (RATHBUN)	C-M
Penaeus bubulus KUBO	N
P. japonicus BATE	S-N-C-M *f*
P. monodon FABRICIUS	N-C-M
P. orientalis KISHINOUYE	N
Trachypenaeus curvirostris (STIMPSON)	S-N-C-M *f*
Solenocera alticraniata KUBO	M
S. brevipes KUBO	C
Sergestidae (Penaeidea)	
Acetes japonicus KISHINOUYE	S-N-C-M *f*

Miho Bay, 29 species in Sakai Channel, 22 species in Lake Naka-umi, while 11 species have been recorded to occur in Lake Shinji-ko. The species occurring in Lake Shinji-ko include 1 species, *Macrobrachium australe*, which has been collected only from there, whereas 6 species, *Eriocheir japonicus*, *Portunus pelagicus*, *Metapenaeus monoceros*, *Penaeus japonicus*, *Trachypenaeus curvirostris* and *Acetes japonicus*, are generally distributed throughout the regions. The most probable explanation of the penetration into Lake Shinji-ko in these salt-water forms, except *Eriocheir japonicus*, is their temporal dispersion under a high chlorinity condition of bottom water in autumn and winter, since they have been caught mostly near River Ohashi-gawa and Sata-gawa Channel.

The decapods of Lake Naka-umi are represented by both fresh-water and marine species, seemingly to reflect the varying intermediate chlorinity of water there (Figs. 2 and 3). *Eriocheir japonicus*, *Macrobrachium nipponense*, *Palaemon orientis*, *Palaemon paucidens* and *Procambarus clarki* are the examples of the former, which have been mostly caught in the marginal shallow waters, and the latter being the majority includes *Charybdis japonica*, *Charybdis bimaculata*, *Protunus pelagicus*, *Philyra pisum*, *Crangon affinis*, *Palaemon ortmanni*, *Palaemon pacificus*, *Palaemon serrifer*, *Alpheus brevicristatus*, *Metapenaeus monoceros*, *Penaeus bubulus*, *Penaeus japonicus*, *Penaeus monodon*, *Penaeus orientalis*, *Trachypenaeus curvirostris* and *Acetes japonicus*. Apart from *Eriocheir japonicus*, the decapods of Miho Bay are all marine and brackish-water forms. These are characterized further, as well as in Lake Naka-umi, by the contributions from both the southern and the cold-water species. Among the former are *Actaea krausii*, *Portunus hastatoides*, *Ovalipes punctatus*, *Leucosia rhomboidalis*, *Penaeus monodon* and *Solenocera alticraniata*, which are known to occur in warm-water or sub-tropical water regions, while *Processa japonica* is an example of the forms

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Notes on some names of species. There have been much confusions in usage among the generic names of *Crago*, *Crangon* and *Alpheus*. The name *Crangon* has been traditionally used for a genus of snapping shrimps ('teppo-ebi') and the name *Crago* for a genus of subchelate shrimps ('ebi-jako') among the Japanese workers (one of exceptions is for example YOKOYA (1933) who used the name *Crangon* for subchelate shrimps; also see KUBO, 1965). These usages were corrected by adopting the name *Alpheus* FABRICIUS 1798 for the former in place of invalid names *Alpheus* WEBER 1795 and *Crangon* WEBER 1795, and the name *Crangon* FABRICIUS 1798 for the latter in place of invalid names *Crangon* WEBER 1795 *Crago* LAMARCK 1801 (the Opinion 334 of the International Commission of Zoological Nomenclature; HOLTHUIS, 1955). The species of genus *Leander* and genus *Palaemon* has been also confused, but the errors in their assignments were finally corrected by adopting the strict definitions of genus *Leander* E. DESMAREST 1849 and genus *Palaemon* WEBER 1795, the latter of which had come to include many of the species formerly belonged to the former (HOLTHUIS, 1952, 1955). By doing so the name *Leander japonicus* ORTMANN was abandoned and the new name *Palaemon* (*Exopalaemon*) *orientis* HOLTHUIS was given to the species (HOLTHUIS, 1955; also see KUBO, 1965), since the specific name *japonicus* was preoccupied (DE HAAN, 1849; DE MAN, 1879; ORTMANN, 1891), though the combinations of *Leander japonicus* and *Palamemon japonicus* has been still used by many workers in Japan.

found also in the cold-water region. Genus *Scyllarus* is, generally speaking, composed of warm-water species, but *Scyllarus kitanoviriosus* has only been known from Seto Inland Sea and Japan Sea.

The decapod fauna of the regions investigated has much common to those of the bays on the southern Pacific coast. Taking the natantian component as an example which has been most widely studied in various areas, 17 out of 31 species caught during the present survey are also represented in the macruran fauna of Kasaoka Bay in Seto Inland Sea (YASUDA, 1956, 1958), which is composed of 33 species, 9 species in that of Tokyo Bay (KUBO and ASADA, 1957), which contains 21 species, and 14 species in that of the Sea of Ariake (MIYAKE, 1961), which includes 27 species. Of these forms 6 species are common to all four areas, that are *Crangon affinis*, *Palaemon serrifer*, *Latreutes planirostris*, *Alpheus japonicus*, *Metapenaeopsis acclivis* and *Trachypenaeus curvirostris*. Most of these species, particularly *Crangon affinis*, are relatively abundant in all these areas here considered. On the contrary, very few species are common to the Naka-umi regions and Matsushima Bay on the northern Pacific coast (SATO, 1957).

There are noticed some differences in occurrence of natantian species among these southern waters. *Crangon affinis*, *Latreutes planirostris*, *Alpheus japonicus*, *Metapenaeopsis acclivis* and *Trachypenaeus curvirostris* are widely distributed in Tokyo Bay, only the first four are found throughout Kasaoka Bay, and in Lake Naka-umi and adjacent regions *Palaemon serrifer* and *Trachypenaeus curvirostris* occur generally. *Metapenaeopsis acclivis* is rather confined to the outer part of the waters both in Kasaoka Bay and the Naka-umi regions. *Processa japonica* has been consistently captured in the outer part in all three waters. Since the conditions of the water, except depth, are not so much unlike between them, these differences in distribution of common species are perhaps due to the difference in intensity and method of collecting.

According to YATSUYANAGI and MATSUKIYO (1951), *Metapenaeopsis barbatus*, *Metapenaeopsis acclivis* and *Trachypenaeus curvirostris* are abundantly fished in the western part of Seto Inland Sea, though this is not the situation in the Naka-umi regions. It is noticeable, moreover, that, although they are absent from the samples of KUBO and ASADA from Tokyo Bay, *Metapenaeopsis barbatus* is distributed in large numbers in Kasaoka Bay, but relatively scarce in the Naka-umi regions, and *Metapenaeus monoceros* and *Penaeus japonicus* occur in the whole areas of the latter two waters.

Changes in Relative Abundance of Some Dominant Species

Apart from the characteristics and differences in decapod faunas of Lake Naka-umi and adjacent regions, a certain amount of evidence has been gained that serves to elucidate biologies of some dominant and important species. From the extensive results of the survey distinct patterns and trends in their occurrence have been recognized, although the comparisons are not possible to base on the exact quantitative assessment of their populations. The specific accounts are given here for those species, in which the results have been accumulated reasonably well, that include *Charybdis japonica*, *Portunus pelagicus*, *Crangon affinis*, *Macrobrachium nipponense*, *Palaemon serrifer*, *Alpheus brevicristatus*, *Metapenaeus monoceros*, *Penaeus japonicus* and *Acetes japonicus*.

Table 2. Seasonal variations in numbers per fishing of principal species captured by a filter net off Moriyama during the period from July 1960 to July 1961.

Species \ Date	July 26-27	August 11-12	September 21-22	October 25-26	December 8-9	January 17-18	February 6-7	March 19-20	April 26-27	May 19-20	June 23-24	July 14-15
No. of Fishing	3	3	4	6	4	4	4	4	3	5	3	4
Charybdis japonica	1.0	1.0	1.0	0.3	0.3	0	0	0	0	0	0.3	0.3
Portunus pelagicus	1.7	5.0	4.0	0	0	0	0	0	0	1.0	1.0	0
Crangon affinis	9.0	119	0	0	3.5	14.8	3.5	7.5	0	3.6	0	5.3
Palaemon serrifer	1.0	104	0.8	0.2	3.5	0	0	3.8	0	5.0	0	0
Alpheus brevicristatus	0.3	1.0	3.5	0	0.3	0	0	25	0	1.4	0.3	0
Metapenaeus monoceros	6.3	3.5	0	0	0	0	0	0	0	0	0	0
Penaeus japonicus	0.3	0	0.8	0	0	0	0	0	0	0	0	0
Acetes japonicus	0	0.3	36	0.8	56.3	0.3	0	29	0	0.8	0	252

The carapace length—body weight relationships are presented in Fig. 4 for some of these species.

Charybdis japonica イシガニ

Charybdis japonica is distributed over various grounds of regions, but it is found in abundance on rocky *Sargassum* belts along the coasts of Miho Bay and Lake Naka-umi. In June 1961, populations were counted directly by diving

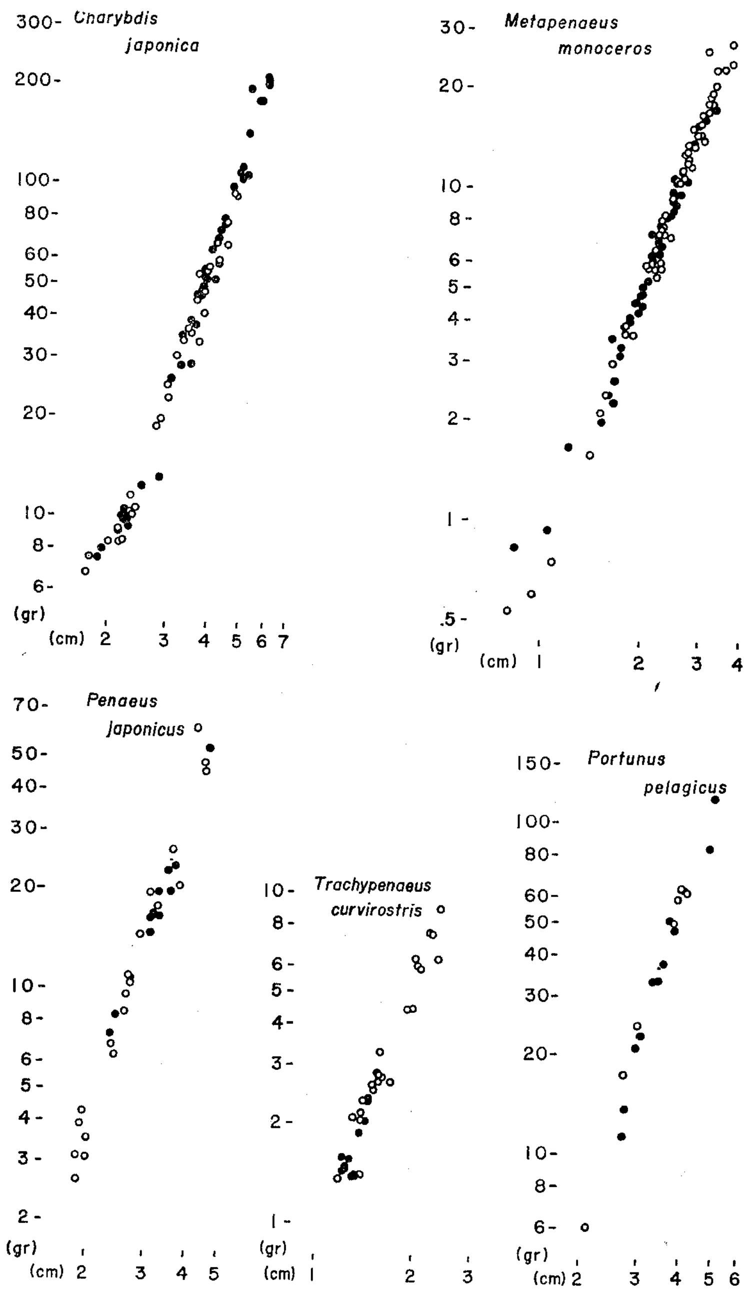

Fig. 4. Carapace length—body weight relations of some dominant decapods. Light circles indicate females and solid circles indicate males.

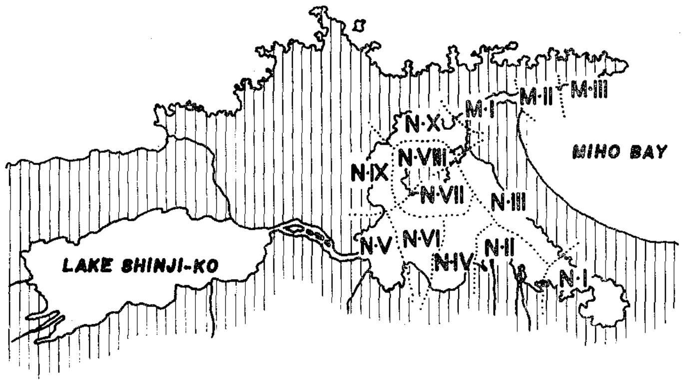

Fig. 5. Chart showing statistical sub-regions into which Lake Naka-umi and adjacent regions are divided for the convenience of treatment and explanation of the results.

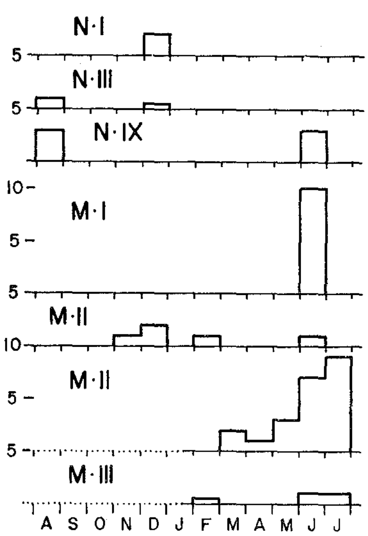

Fig. 6. Seasonal variations in the catch per a day's fishing of *Charybdis japonica* with a guiding barrier, operated monthly during the period from August 1960 to July 1961 in different sub-regions, in comparison with those with trammels in Miho Bay (bottom two).

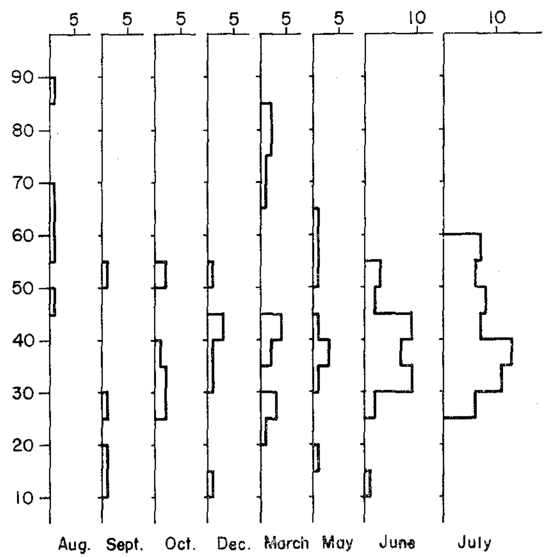

Fig. 7. Seasonal variation in carapace length frequency distribution of *Charybdis japonica* from the whole area, collected by various gears during the period from August 1960 to July 1961. Carapace length in mm.

observation and were found to range between 0.48 and 0.60 individuals per square metre on the grounds with *Sargassum* growth off Fukuura and Moriyama and with mixed growth of *Sargassum* and *Zostera* in northern Naka-umi.

It will be seen from Fig. 6, though the numbers captured were generally small, that a trend of increase in the catch towards Miho Bay is evident.

It will also be observed from Fig. 6 and Table 2 that there are pronounced decreases in the catch of the species during the winter months, or almost complete disappearance from the catches from Lake Naka-umi in January to March, although somewhat prolonged capture is recorded from rocky bottom in Miho Bay by trammels. Assumingly the activity of the species diminishes in winter, and slightly higher temperature of water is responsible for the latter case.

Day-night differences in the catch are not evidently seen from Fig. 8. These data appears to reflect that there are no distinct diurnal changes of activity in the present species at least in the summer season.

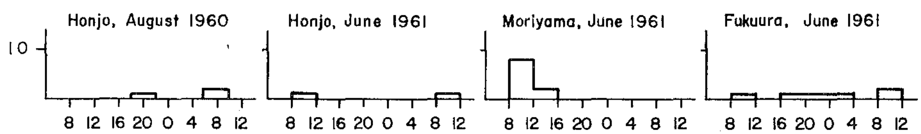

Fig. 8. Diurnal variations in the catches of *Charybdis japonica* with a guiding barrier, recorded for four hours' intervals.

The size distributions obtained (Fig. 7) are relatively uniformative and there are no significant indications of prominent age groups and their successive growth. However, since high percentages of ovigerous females were found in June and a large number of small individuals, less than 10 mm in carapace length, which are not shown in Fig. 7 because of loss of specimens and precise records of measurement, were observed in the filter net catches in August 1960, the dominant size groups of around 40 mm in carapace length in June and July may presumably be 1 year old and the larger individuals appearing in March and August 2 years old or older.

Portunus pelagicus タイワンガザミ

This species also occurs in all regions of the survey and, differing from *Charybdis japonica* which was predominantly captured on the coastal areas of Miho Bay by trammels, appears to be abundant on the level bottom of Lake Naka-umi where guiding barriers are operated (Fig. 9). Populations counted by diving observarion were generally around 0.4 individuals per square metre on *Sargassum* belts on the north coasts of Lake Naka-umi and Miho Bay.

There are noticed considerable increases in the catches in all sub-regions during the summer and autumn months, whereas almost complete disappearance from the winter catches is shown in Fig. 9 and Table 2. Day-night differences in the catch are apparent (Fig. 10) and the numbers captured during the night were generally many times larger than that caught during the day. These differences seem to be sustained substantially by the seasonal and diurnal changes of activity and not to be interpreted in terms of distribution.

It is evident from an examination of Fig. 11 that the progressive change in the size composition is quite obscure. A group is, however, strongly represented around a carapace length of 40 mm in the months of October to July. Since berried females were found most abundantly in the June and July catches and the smallest group in September which measured in carapace length around 10 mm can be regarded as the new season's 0-group, this dominant group is considered to be that has completed a full year. The subsequent growth of this group and the growth of larger groups are uneasy to be followed.

Crangon affinis エビジャコ

The distribution of *Crangon affinis* is relatively limited. It occurs mostly in the eastern Naka-umi, particularly abundant in the Sakai Channel area.

It will be clearly seen from Table 2 that there were considerable variations in the catch of this species by a filter net in Sakai Channel. With an exception of high values of the August

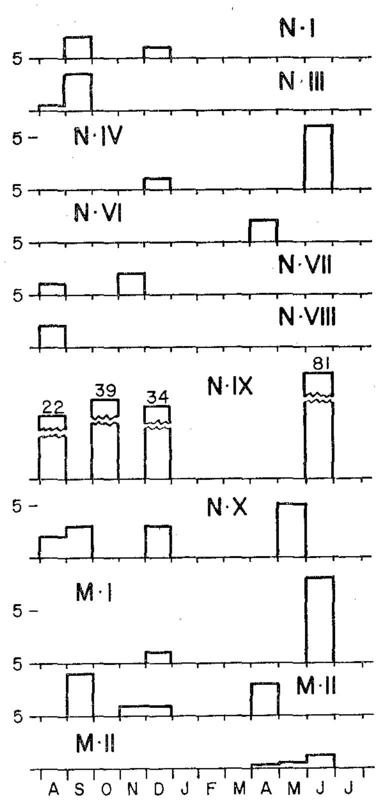

Fig. 9. Seasonal variations in the catch per a day's fishing of *Portunus pelagicus* with a guiding barrier, operated monthly during the period from August 1960 to July 1961 in different sub-regions.

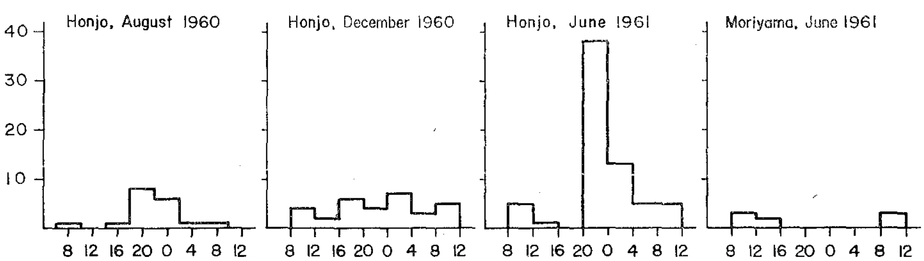

Fig. 10. Diurnal variation in the catches of *Portunus pelagicus* with a guiding barrier, recorded for four hours' intervals.

sample, the summer catches were in general markedly small.

Samples taken by a filter net in Sakai channel showed a good contrast in numbers of this species captured between day and night (Fig. 12). It was almost exclusively found in the night catches throughout the year and moreover in those obtained by receiving outflow currents. It is apparent from these

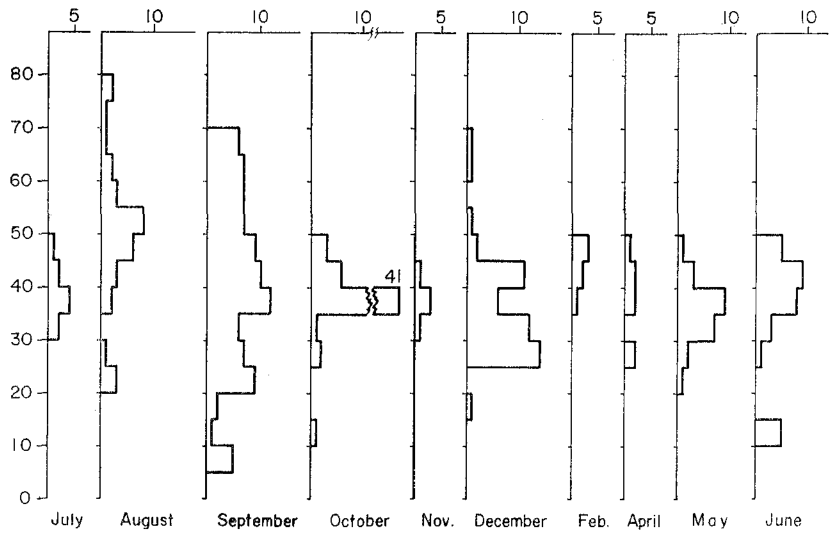

Fig. 11. Seasonal variation in carapace length frequency distribution of *Portunus pelagicus* from the whole area, collected by various gears during the period from August 1960 to July 1961. Carapace length in mm.

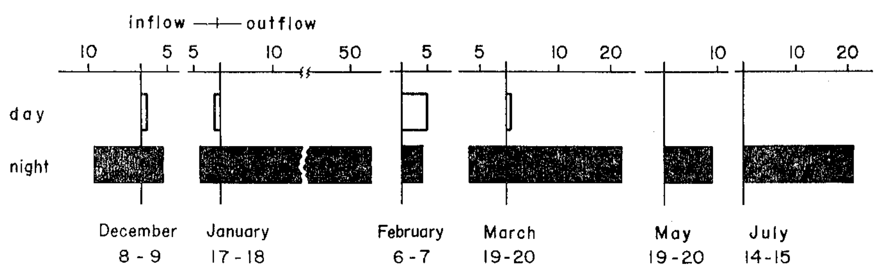

Fig. 12. Variations in the catches of *Crangon affinis* with a filter net in relation to tidal stream and time of the day. Off Moriyama in Sakai Channel, 1960 to 1961.

results that the species has the nocturnal habit of swimming, but the reasons why the species is not captured in the inflow current, as in the case of other species, are not certain and not explained in terms of seasonal migration or life-cycle.

Berried females appear in January and February, breeding size being over

8 mm in carapace length. The January and February samples show a clear bimodal distribution of size, and the upper peak around 9 mm is solely consisted of females, while the lower one around 6 mm is predominantly of males. The separation in size between female and male, as seen in the samples of these months, is much more vague in the samples of other seasons, which contain smaller individuals. The dominant groups with a peak around 3 mm in the July to December samples seem to represent the 0-group, and, accordingly, little appears to occur during that period, while the growth after December is very rapid.

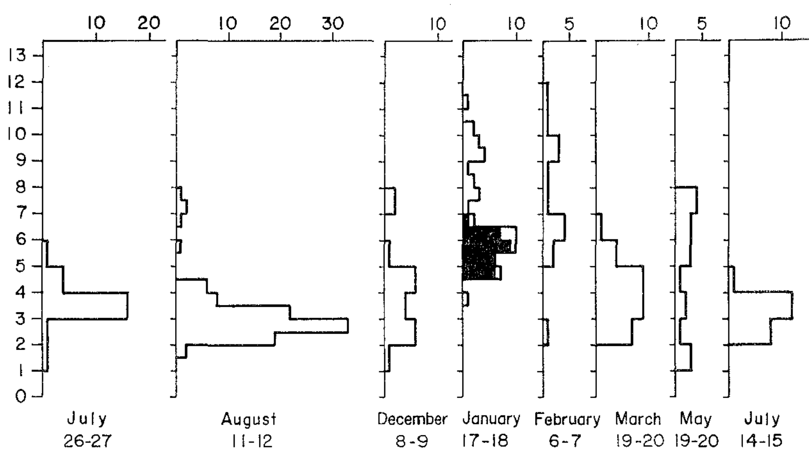

Fig. 13. Seasonal variation in population composition of *Crangon affinis* from Sakai Channel, collected by a filter net during the period from July 1960 to July 1961 off Moriyama. Carapace length in mm. Solid portions for January 1961 indicate males.

Macrobrachium nipponense テナガエビ

This species is the freshwater species, but has been frequently collected in Lake Naka-umi.

The increased catches by filter nets have been recorded in River Ohashi-gawa during the period from May to August, whereas in the northern part of Lake Shinji-ko the relatively large samples have been taken during the autumn months (Fig. 14). The summer samples are shown to be composed generally of individuals of large size (Fig. 15). It may be probable that the species migrates seasonally between Lake Shinji-ko and River Ohashi-gawa, larger individuals moving to the shallower waters in summer and younger individuals spending winter months in Lake Shinji-ko.

Palaemon serrifer スジエビモドキ

Palaemon serrifer is mostly caught in Lake Naka-umi and Sakai Channel, particularly abundant in the *Zostera* and *Sargassum* growths. The numbers captured by a filter net in Sakai Channel are generally larger in the spring to summer samples, and are exclusively recorded during the night (Table 2 and Fig. 16).

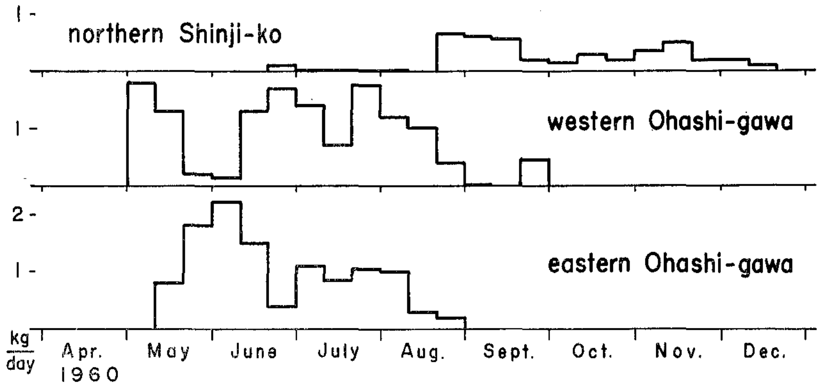

Fig. 14. Seasonal variations in mean daily landing per a gear by each third of month for *Macrobrachium nipponense* caught with filter nets in three different regions.

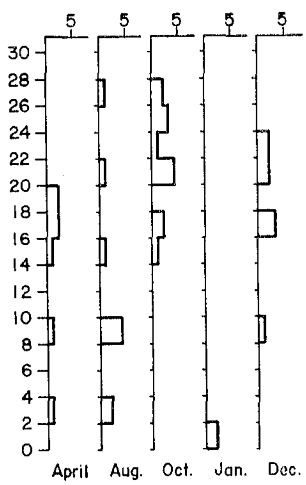

Fig. 15. Seasonal variation in carapace length frequency distribution of *Macrobrachium nipponense* from the whole area, collected by various gears during the period from April 1959 to December 1960. Carapace length in mm.

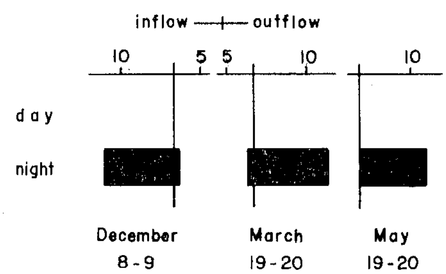

Fig. 16. Variations in the catches of *Palaemon serrifer* with a filter net in relation to tidal stream and time of the day. Off Moriyama in Sakai Channel, 1960 to 1961.

Berried females were found in the March to August samples. The dominant size groups are clearly seen in the August to June samples, from which a progressive shift is distinctly recognizable as the season proceeds, presumably leading to the larger groups in the August and October samples (Fig. 17).

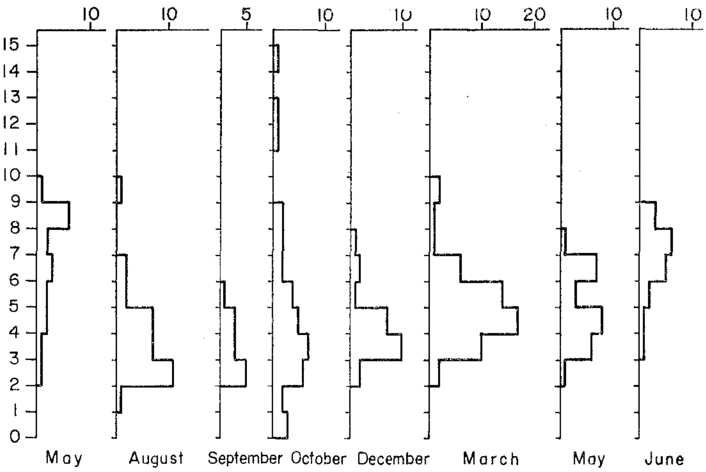

Fig. 17. Seasonal variation in carapace length frequency distribution of *Palaemon serrifer* from the whole area, collected by various gears during the period from May 1960 to June 1961. Carapace length in mm.

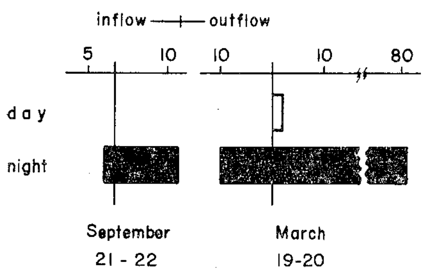

Fig. 18. Variations in the catches of *Alpheus brevicristatus* with a filter net in relation to tidal stream and time of the day. Off Moriyama in Sakai Channel, 1960 to 1961.

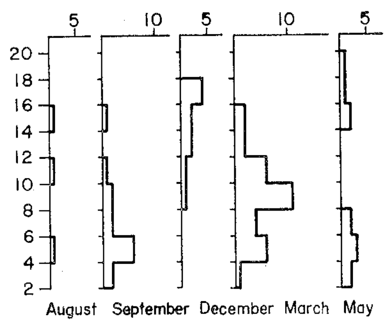

Fig. 19. Seasonal variation in carapace length frequency distribution of *Alpheus brevicristatus* from the whole area, collected by various gears during the period from August 1960 to May 1961. Carapace length in mm.

Alpheus brevicristatus テッポウエビ

This species occurs on the muddy bottom of Lake Naka-umi to Miho Bay throughout a year. It has been also recorded in the catches by a filter net operated off Moriyama in Sakai Channel in nearly every month, but there is no clear indication of seasons in which the species is captured in particular abundance (Table 2). Successful collections by a filter net were, as in other species, mostly restricted to the night (Fig. 18). That the species was collected relatively few in number in all seasons makes it very difficult to follow growth from the size composition histograms (Fig. 19).

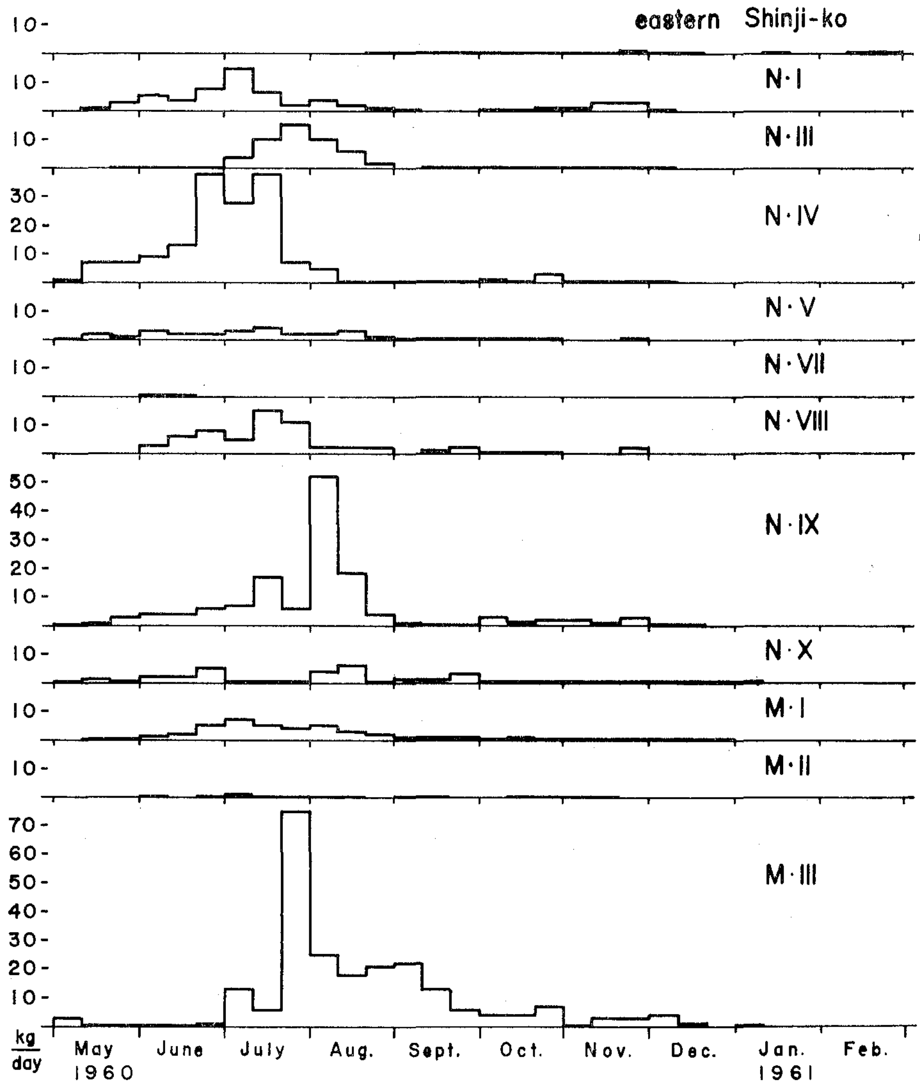

Fig. 20. Seasonal variations in mean daily landing per a gear by each third of month for *Metapenaeus monoceros* caught with the guiding barriers in different sub-regions.

Metapenaeus monoceros ヨシエビ

Metapenaeus monoceros in Lake Naka-umi and Lake Shinji-ko has been well studied by OTA (1949).

From the results of the present survey, the increased landings are clearly seen to be reached in summer in all sub-regions, the time of the peak tending to come later in a year in those closer to the open sea (Fig. 20). The prolonged catches by the guiding barriers in these outer areas are probably the indication of the species remaining active by mid-winter there, although these may be accounted for partly by migration to the open sea in winter. By March *Metapenaeus monoceros* ceases to be fished by guiding barriers in any area.

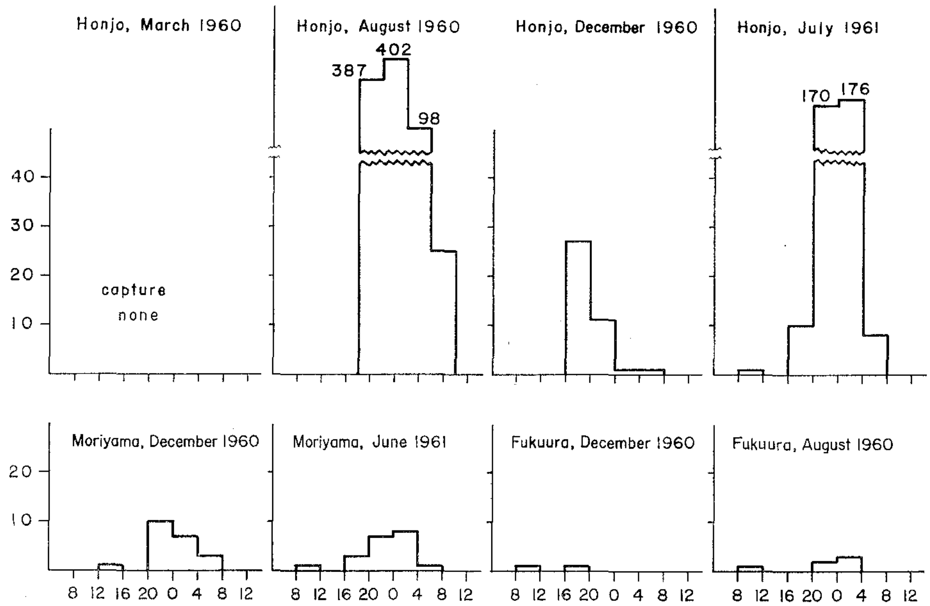

Fig. 21. Diurnal variations in the catches of *Metapenaeus monoceros* with a guiding barrier, recorded for four hours' intervals.

The examination of the catches taken with guiding barriers at the intervals of 2 hours reveals that *Metapenaeus monoceros* is generally captured during the night. It is particularly remarkable in summer in Honjo area where the highest landings are recorded. This variation in numbers can directly be related to the diurnal change in active movement of the species.

The size compositions of the monthly samples are presented in Fig. 22. The smaller prawns are represented in the samples of May to September. The progressive growth of this group is not clearly followed, due to lack of measurements of autumn samples. Presumably the majority of these smaller prawns reach to 15 mm in carapace length by the end of the year and make up the dominant group of around 25 mm in carapace length in next June.

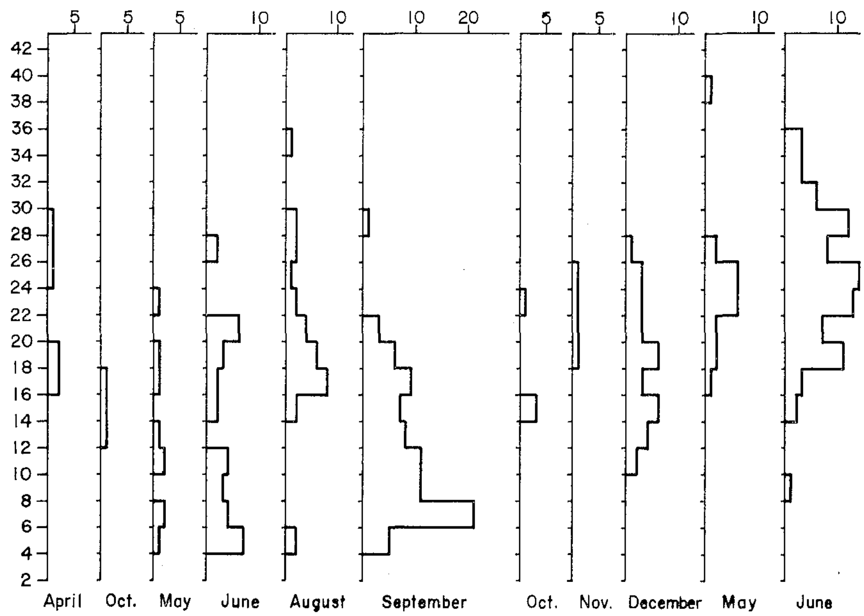

Fig. 22. Seasonal variation in carapace length frequency distribution of *Metapenaeus monoceros* from the whole area, collected by various gears during the period from April 1960 to June 1961. Carapace length in mm.

Penaeus japonicus クルマエビ

Although the records of collection of this species have been obtained from over quite a wide area of the regions, a pronounced difference is well recognized in the amount of its landings among the regions. The good catches were mostly resulted from Miho Bay and Sakai Channel, while small collections which were also restricted in season to the summer months were obtained in Lake Naka-umi and only few were caught in Lake Shinji-ko (Fig. 23). The larger catches were taken in the summer months, but here again a trend is evident that the peak of fishing is reached later in a year in outer sub-regions and the fishing season continues longer there. No samples were taken during the remainder of the year.

The examination of samples collected from Lake Naka-umi and Miho Bay revealed that there was a difference in sex ratio of populations. The samples collected in Lake Naka-umi showed without exception that the percentages of females exceeded that of males, whereas in Miho Bay the opposite was observed. The occurrence of the species only for a restricted period in a year in Lake

Naka-umi is supposed to be related with breeding migration.

Size compositions are shown for each month in Fig. 24. Owing to the small numbers of measurements the growth is hardly followed.

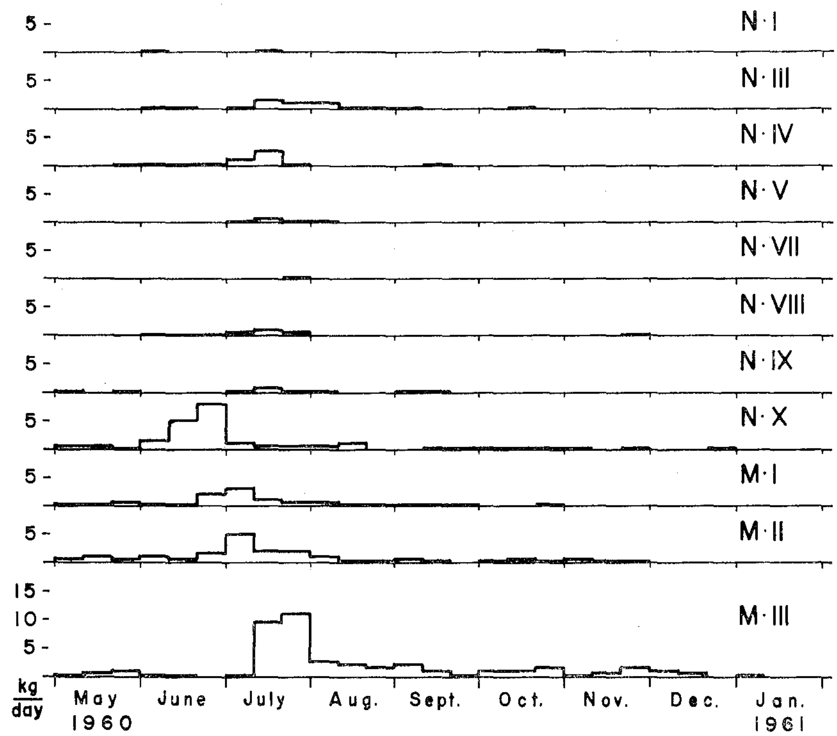

Fig. 23. Seasonal variations in mean daily landing per a gear by each third of month for *Penaeus japonicus* caught with the guiding barriers in different sub-regions.

Acetes japonicus アキアミ

This species occurs most abundantly in Lake Naka-umi. The increased catches by trawling on *Zostera* belts were recorded in autumn, the month of the highest collections differing between the sub-regions. Small increases in number of the species caught were also recorded in spring (Fig. 25). It will be seen from the results of collection by a filter net (Table 2) that large samples were taken in separate months. Any further trend can not be abstracted from their occurrence.

Since *Acetes japonicus* is known to be a more or less pelagic form, the sporadic occurrence may assumingly be the result of migration, and, although the species distributes over a wide area of the regions, its shoals appear to

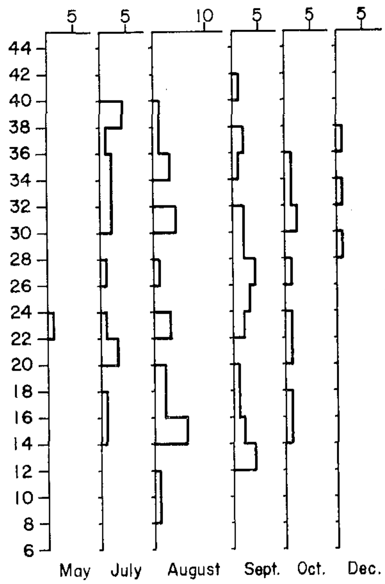

Fig. 24. Seasonal variation in carapace length frequency distribution of *Penaeus japonicus* from the whole area, collected by various gears during the period from May to December 1960. Carapace length in mm.

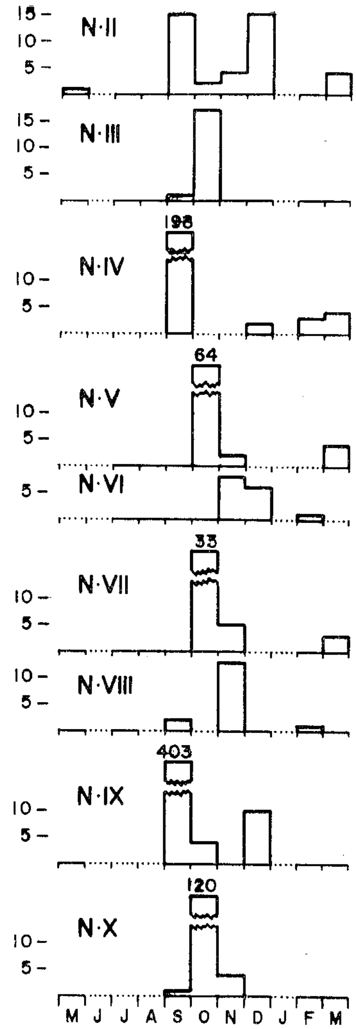

Fig. 25. Seasonal variations in the catch per a haul of *Acetes japonicus* with a trawl, operated monthly during the period from May 1960 to March 1961 on *Zostera* belts in different sub-regions.

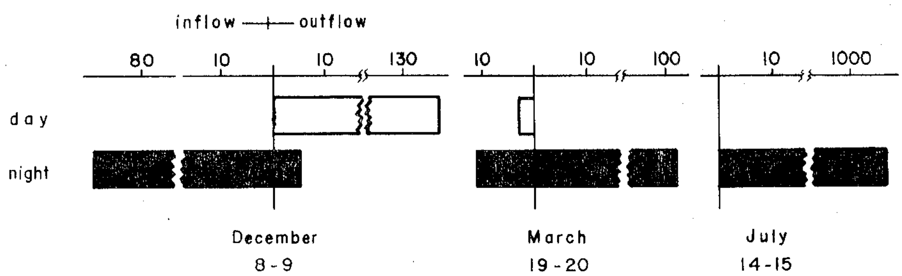

Fig. 26. Variations in the catches of *Acetes japonicus* with a filter net in relation to tidal stream and time of the day. Off Moriyama in Sakai Channel, 1960 to 1961.

gather on a restricted part of the area. Although the majority of the collections by a filter net were taken during the night, large catches were also made in the day, which could be taken as an indication of the pelagic habit of the species (Fig. 26).

Acetes japonicus in Seto Inland Sea is reported to have a short summer generation (YASUDA and others, 1953). The occurrence of smaller individuals of this generation in early summer is not apparent in the present results, though the recruitment of the new brood in September and the rapid growth in the spring months are shown in the monthly size-composition (Fig. 27).

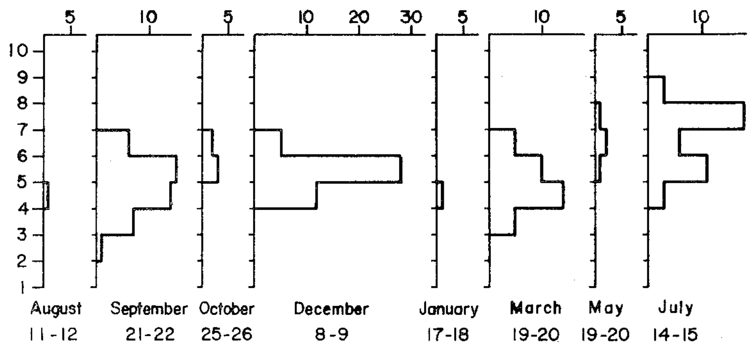

Fig. 27. Seasonal variation in population composition of *Acetes japonicus* from Sakai Channel, collected by a filter net during the period from August 1960 to July 1961 off Moriyama. Carapace length in mm.

Production of Decapods

It is apparent from the results presented above that Lake Naka-umi is utilized by most varied species of decapod crustaceans and holds abundant populations. This is also shown in commercial catches of decapod crustaceans estimated on the basis of daily records kept by fishermen (Fig. 28).

Annual catches from Lake Naka-umi are more than 4 times larger than that of Lake Shinji-ko and nearly 10 times larger than that of Miho Bay. Even when the area is taken into account, that is, by comparing the yield per unit area, annual landings from Lake Naka-umi are 3 times larger than that of Lake Shinji-ko. The major part of landings are represented by macrurans, but the percentages of brachyurans are larger in Miho Bay and Sakai Channel.

Since most of these dominant decapod species are migratory, they utilize different grounds as habitats at different stages of life-cycle. This has been also pointed out for shrimps in Seto Inland Sea by YASUDA and others (1957). The biological production of these animals in the sense of the growth in biomass is therefore not strictly represented by the fishery production which is virtually composite in relation to the area. Only with this reservation the latter could be taken as a rough indication of the former. As far as the species composition and the fishery production are concerned, Lake Naka-umi of brackish and shallow water appears to be most productive.

The higher rate of biological production in Lake Naka-umi has been suggested on the basis of phosphorus budget by MORI (1964). The total standing

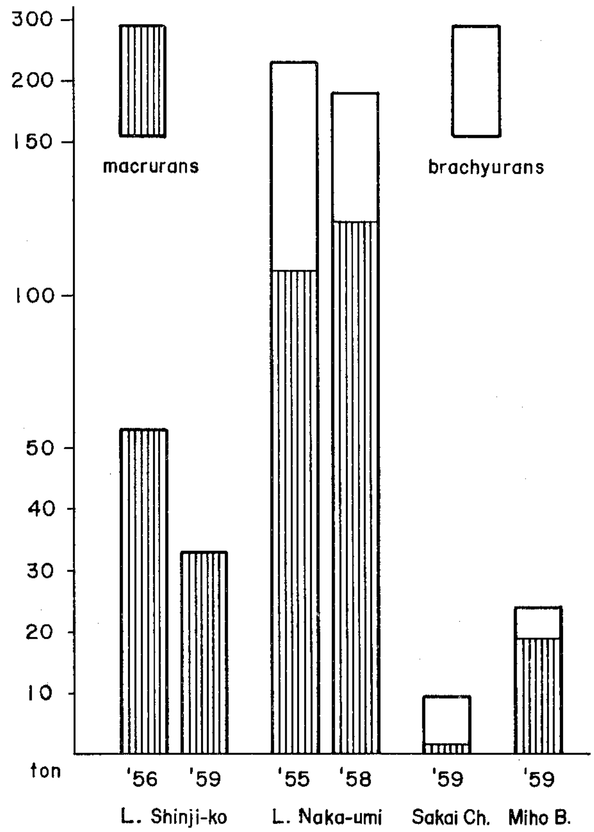

Fig. 28. Estimated values of commercial catches of decapods, based on the data calculated by KAWANABE (unpublished) from the records and interviews of fishermen.

crop of macro-benthic animals of Lake Shinji-ko is calculated to be generally greater than that of Lake Naka-umi, except in spring when the maximum value has been estimated for Lake Naka-umi, suggesting a high level of production (KIKUCHI, 1964). The plankton counts also insinuate the greater amounts of biomass in Lake Naka-umi (unpublished data of the survey, which will be treated elsewhere). The fishery production and estimated amount of biological production of fishes are also reported to be greater in Naka-umi (KAWANABE et al., 1968). These trends are consistent with the present results of decapod crustaceans. Presumably the higher level of biological production in Lake Naka-umi owes much, at least in the present case, to the complexity of species composition resulted from the complex feature of the region and varied utilization of it by the animals.

Summary

Decapod crustaceans were collected with various gears in the course of the ecological survey of Lake Naka-umi and adjacent regions during the period of 1958–1962.

The list of species recorded in the survey is presented in Table 1. Altogether 18 spp. of brachyurans, 4 spp. of anomurans, 2 spp. of macrurous reptantians, 15 spp. of carideans, and 16 spp. of penaeideans have been recorded to occur in the regions.

There are noticed some similarities in species composition between the present area and Tokyo Bay, Kasaoka Bay and the Sea of Ariake. *Palaemon serrifer*, *Latreutes planirostris*, *Alpheus japonicus*, *Metapenaeopsis acclivis* and *Trachypenaeus curvirostris* are common to occur in these water.

Most varied species occur in Sakai Channel and Lake Naka-umi. The species of most abundant occurrence, namely *Charybdis japonica*, *Portunus pelagicus*, *Crangon affinis*, *Macrobrachium nipponense*, *Palaemon serrifer*, *Alpheus brevicristatus*, *Metapenaeus monoceros*, *Penaeus japonicus* and *Acetes japonicus*, are treated separately for distribution, seasonal abundance and growth.

From the daily records of the catch of each species kept by fishermen the highest value of fishery landings is estimated to have been yielded in Lake Naka-umi.

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